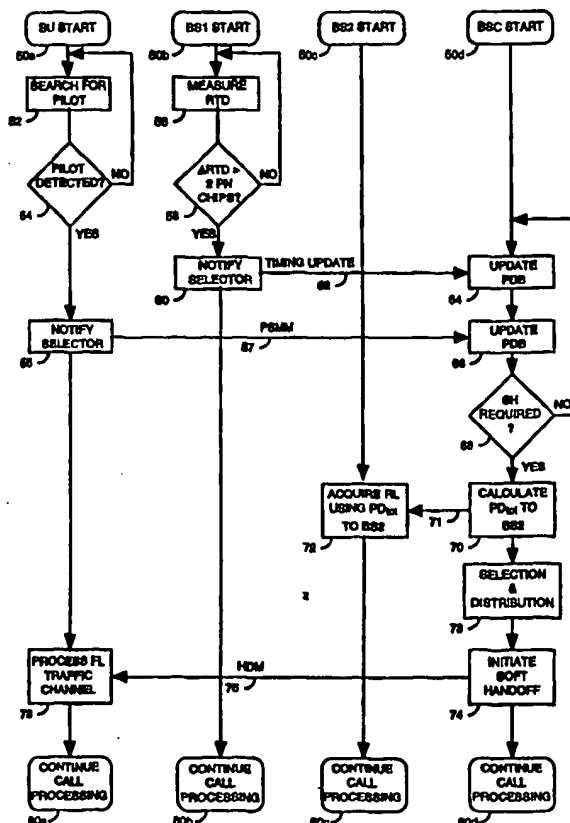




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(54) Title: A METHOD OF AND APPARATUS FOR TRACKING PROPAGATION DELAY BETWEEN A BASE STATION AND A SUBSCRIBER UNIT		
(57) Abstract A method of and apparatus for tracking propagation delay between a base station and a subscriber unit is described. The method and apparatus may be used in performing an efficient soft handoff in a cellular telephone system. In one embodiment a round trip delay between a base station (32a, 32b) and a subscriber unit (30) is tracked. Changes in the round trip delay at the base station (32a, 32b) are monitored, and updates sent to a base station controller (36) when the delay changes by more than a predetermined amount. Using round trip delay from a first base station and a pilot PN code phase for a pilot received from a second base station, an estimated arrival state of a reverse link signal from the subscriber unit (30) to the second base station is calculated. The estimated arrival state aids acquisition of the reverse link signal by the second base station.		



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A METHOD OF AND APPARATUS FOR TRACKING PROPAGATION DELAY BETWEEN A BASE STATION AND A SUBSCRIBER UNIT

5 BACKGROUND OF THE INVENTION

I. Field of the Invention

10 The present invention relates to a method of and apparatus for tracking propagation delay between a base station and a subscriber unit. The present invention may be applied to efficiently performing a soft handoff of a subscriber unit moving from the coverage area of a first base station to the coverage area of a second base station.

15 II. Description of the Related Art

The IS-95 standard (IS-95) defines a Code Division Multiple Access (CDMA) over-the-air interface for providing efficient and robust cellular telephone service. The IS-95 standard has been approved by the
20 Telecommunication Industry Association (TIA) to allow cellular telephones and base stations manufactured by different suppliers to interoperate with one another. An illustration of a cellular telephone system configured in accordance with the use of the IS-95 standard is provided in FIG. 1. Also, a cellular telephone system configured substantially in accordance with the
25 use of IS-95 is described in US patent 5,103,459 entitled "System and Method for Generating Signal Waveforms in a CDMA Cellular Telephone System" assigned to the assignee of the present invention and incorporated herein by reference.

CDMA signal processing allows a set of user signals to be transmitted
30 over the same radio frequency (RF) band by modulation of the user signals with a set of pseudorandom noise codes (PN codes) before upconversion to an RF frequency band. The PN codes are used to modulate and demodulate the user signals for transmission and reception processing respectively. Transmitting a set of user signals over the same RF frequency range
35 increases the number of transmission that can be conducted over a given amount of RF bandwidth, by increasing the frequency factor of the cellular telephone system.

To provide increased robustness over prior art cellular telephone systems, IS-95 performs soft handoff as a subscriber unit 10 (typically a
40 cellular telephone) moves from the coverage area of one base station 12 to

the coverage area of another base station 12. Soft handoff is the process of establishing an RF link with the second base station 12 before terminating the RF link with the first base station. In FIG. 1, one subscriber unit 10 is shown interfacing with two base stations 12 and therefore in soft handoff.

5 Soft handoff can be contrasted with hard handoff during which the RF link with the first base station 12 is terminated before the RF link with the second base station is established. By maintaining at least one RF link at all times, soft handoff increases the likelihood that the telephone call will continue uninterrupted during the transition from one coverage area to
10 another.

To properly perform CDMA signal processing, the state of PN codes used to process the user signals at the receive system must be the same as the state of the PN codes used at the transmit system. Thus, for processing the forward link transmission from a base station 12 to a subscriber unit 10, the
15 PN codes at the subscriber unit 10 must be set to the state of the PN codes at the base station 12 plus some additional time equal to the propagation delay experienced during the transmission of the RF signals.

Similarly, for processing the reverse link transmission from a subscriber unit 10 to a base station 12, the PN codes at the base station 12
20 must be set to the state of the PN codes at the subscriber unit 10 plus some additional time equal to the propagation delay.

In accordance with the IS-95 standard, each PN code used to generate the pilot channel from each base station 12 is phase offset by multiples of 64 bits, or "chips", with respect to the phase of the pilot PN codes at the other
25 base stations 12. The phase offset is set to $64 \cdot \text{PILOT_PN}$, where PILOT_PN is a pilot PN offset index that uniquely identifies a base station 12 from other proximately located base stations 12. The phase offset allows a subscriber unit 10 to identify different base stations 12. The reverse link signals are modulated with a similar PN code, but without the use of an PN code offset.
30 Rather, subscriber units 10 are identified using an additional code that is unique to each subscriber unit.

To establish a bidirectional RF link between a subscriber unit 10 and a base station 12, both the forward and reverse link signals must first be acquired. That is, the PN codes used at the receive and transmit systems
35 must be synchronized. When conducting a soft hand-off, any delay in the process of acquiring the reverse link signal is undesirable because, until the acquisition takes place, the IS-95 reverse link power control mechanism cannot be attempted. Without reverse link power control, the reverse link signal from the subscriber unit 10 is generated at excessively high levels, and

therefore unduly interferes with the transmission of other subscriber units
10 operating in the coverage area of the second base station 12. Thus, to
improve the performance of a cellular telephone system, the present
invention is directed to reducing the time necessary to perform reverse link
5 signal acquisition during a soft hand-off.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a novel and
10 improved method and apparatus for efficiently performing a soft handoff in
a cellular telephone system.

In one aspect the invention provides a method for tracking a first
propagation delay between a first base station and a subscriber unit
comprising: tracking changes in the first delay to said first base station; and
15 notifying a base station controller when said first delay changes by a
predetermined amount.

In another aspect the invention provides a system for providing
wireless communications, the system comprising: subscriber unit for
generating pilot strength measurement report indicating a phase offset of
20 received pilot channel; first base station for generating a timing update
message when a first propagation delay between said first base station and
said subscriber unit changes more than a predetermined amount; base
station controller for generating an estimated delay using said phase offset
and said first delay; and second base station for performing a signal
25 acquisition initiated at said estimated delay.

In a further aspect the invention provides a wireless
telecommunications system for tracking a first delay to a subscriber unit
comprising: a base station for generating a timing update message when said
first delay changes by a predetermined amount; and a base station controller
30 for updating a pilot database using said timing update message.

The invention also provides a wireless telecommunications system for
tracking a first delay to a subscriber unit comprising: transmission means for
generating a timing update message when said first delay changes by a
predetermined amount; and controller means for updating a pilot database
35 using said timing update message.

The invention further provides a controller for controlling
communication with a subscriber unit by measuring the time taken for a
signal to travel from one communication system and back via the subscriber

unit and selecting either the one or another communication system for communication with the subscriber unit depending on the time taken.

In one embodiment of the invention, a propagation delay between a base station and a subscriber unit is tracked. The tracking is performed by monitoring changes in the round trip delay at the base station, and notifying a base station controller when a change exceeding a predetermined amount occurs. Using the round trip delay, and a pilot PN code phase of a pilot channel from a second base station, an estimated arrival state of a reverse link signal from the subscriber unit to the second base station is calculated. This estimated arrival state facilitates acquisition of the reverse link signal by the second base station.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below of an embodiment of the invention when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is an illustration of a cellular telephone system configured in accordance with the use of the IS-95 standard;

FIG. 2 is a block diagram of a portion of cellular telephone system configured in accordance with an exemplary embodiment of the invention;

FIG. 3 is a flow chart of the operation of the various systems that make up the cellular telephone system in accordance with one embodiment of the invention; and

FIG. 4 is a timing diagram illustrating the calculation of the arrival state when performed in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A novel and improved method and apparatus for performing an efficient soft handoff is described. In the following description, the embodiment of the invention is set forth in the context of a CDMA cellular telephone system operating in accordance with the IS-95 standard. While the invention is especially suited for operation with a cellular telephone

system operating in accordance with the IS-95 standard, other wireless communication systems including satellite based systems may incorporate the use of the present invention, as may wireline systems that incorporate the use of sinusoidal signals such as coaxial cable communications systems.

5 FIG. 2 is a block diagram of a portion of cellular telephone system configured in accordance with an exemplary embodiment of the invention. In the location shown, subscriber unit 30 has established a bidirectional RF link with base station 32a. Base stations 32a and 32b are coupled to CDMA interconnect subsystem (CIS) 40 via wire line connections.

10 CIS 40 is located within base station controller (BSC) 36 and is coupled to selector subsystem 38, and management system 44. The various systems that make up BSC 36 as well as base stations 32 exchange data and control information via the use of network packets which contain an address that allows routing by CIS 40. During operation, management system 44
15 configures and controls selector subsystem 38 and base stations 32 using subscriber information contained in subscriber data base 46.

 In accordance with the IS-95 standard, each base station 32 transmits a forward link RF signal comprised of a set of subsignals referred to as channels. The channels include a pilot channel which facilitates acquisition
20 and processing of the forward link signal, as well as a set of traffic channels, each of which is used to conduct the forward link portion of a telephone call with a subscriber unit 30.

 As shown, base station 32a is interfacing with subscriber unit 30, and therefore one traffic channel from base station 32a is being used to transmit
25 to subscriber unit 30. Additionally, subscriber unit 30 is transmitting a reverse link signal that is being received and processed by base station 32a. Data transmitted via the forward and reverse link signals is processed in frames of 20 ms duration.

 Frames received by base station 32a are routed in network packets to
30 selector subsystem 38 via CIS 34. Selector subsystem 38 allocates a selector resource (selector) for each call being processed by a corresponding subscriber unit 30. In the preferred embodiment of the invention, the selector is a set of software instructions executed on one or more microprocessors (not shown).

35 The selector resource performs various functions that allow mobile communications to take place. One function is keeping track of the set of pilot channels that have recently been detected by the subscriber unit 30 determine when a soft handoff is required. The pilot channel information is stored in a pilot database (PDB) that is updated by the selector in response

to pilot strength measurement message (PSMM) received from subscriber unit 30. Subscriber unit 30 generates a PSMM when it detects a pilot channel from other base stations 32 with sufficient strength and duration during periodic searches for pilot channel performed during the course of conducting a telephone call or other communication.

For each base station 32 interfacing with a subscriber unit 30 the selector also tracks the round trip delay of a transmission from base station 32 to subscriber unit 30 and back. The round trip delay (RTD) is measured by each base station 32 and reported back to the selector. The base station 32 measures the RTD by monitoring the difference in the state of the PN codes used to demodulate the earliest usable reverse link signal from the subscriber unit 30 and the state of a zero offset PILOT_PN sequence. The state of the PN code used for demodulation is constantly adjusted at the base station 32 to track changes in the arrival time of the reverse link signal as the subscriber unit 30 moves. Thus, the round trip delay to subscriber unit 30 is continuously tracked by the base station 32.

In one embodiment of the invention, each base station 32 reports the round trip delay to the selector when a change more than two PN code bits, or "chips," occurs. The round trip delay is reported to the selector using a timing update signaling message transmitted from the base station 32. The selector responds by updating the PDB to indicate the new round trip delay.

By reporting the round trip delay only when a change of more than 2 PN chips occurs, the number of signaling messages that must be exchanged between the base station 32 and the selector within BSC 36 in order to maintain an accurate round trip delay in the PDB is reduced. Reducing the number of signaling messages decreases the network resources, required for orderly operation of the cellular telephone system. Additionally, the accuracy of the round trip delay that is stored in the PDB is maintained within 2 PN chips.

While a threshold of 2 PN chips for reporting the round trip delay is preferred, the use of other durations may be employed in alternative embodiments of the invention. In the case where alternative thresholds are used, a duration that is greater than 2 PN chips is preferred, because using a duration of less than 2 PN chips unnecessarily increases the number of signaling messages transmitted between the base station 32 and the selector, thus reducing the overall signaling capacity of the cellular network.

This round trip delay reporting method can be contrasted with, for example, the periodic transmission of signaling messages indicating the round trip delay between the subscriber unit 30 and the base station 32.

Periodically transmitting round trip delay update messages would increase the number of signaling messages transmitted for each telephone call, and when a significant number of telephone calls are being conducted the number of timing update messages generated would interfere with the capacity of the cellular system to process user data, which is the primary purpose of the cellular telephone system.

In an alternative embodiment of the invention, the base station 32 reports the round trip delay using changes in the round trip delay, or "delta" values, rather than the absolute value of the round trip delay. For example, when the round trip delay increases by 3.5 ms, the base station 32 transmits a signaling message that includes the 3.5 ms value. When the round trip delay decreases by 3.5 ms, the base station 32 transmits a signaling message that includes a negative 3.5 ms value. Typically, reporting a delta value requires fewer information bits than reporting an absolute value, which further reduces the amount of data necessary to maintain an accurate measure of the round trip delay.

The selector performs call selection and call distribution in addition to the processing described above. Call selection involves selecting a single network packet from a set of network packets received from the set of base stations with which a subscriber unit 30 is interfacing during soft handoff. The selected packet is then used for further processing. Call distribution is the duplication and distribution of network packets to the set of base stations 32 in communication with a subscriber unit 30 during soft handoff so that each base station 32 may transmit the data frame contained in the network packet to the subscriber unit 30 via the forward link signal.

FIG. 3 is a flow chart illustrating the steps performed by subscriber unit 30, first and second base stations 32a and 32b, and a selector within selector subsystem 38 during an exemplary telephone call performed in accordance with one embodiment of the invention. The processing begins at steps 50a - d during an ongoing call in which a subscriber unit 30 is interfacing with base station 32a.

At step 52, subscriber unit 30 searches for pilot channels from other base stations 32 while continuing to process the telephone call. If, at step 54, subscriber unit 30 determines that a pilot channel from another base station was not detected with sufficient strength and duration, step 52 is performed again.

If, at step 54, subscriber unit 30 determines that a pilot channel from another base station 32, such as the second base station 32b, was detected with sufficient strength and duration, subscriber unit 30 notifies the selector

within BSC 36 via pilot strength measurement message (PSMM) 57, transmitted at step 55. Typically, detection of the pilot channel from another base station such as the second base station 32b corresponds to entry into the coverage area of the second base station 32b.

5 In the preferred embodiment of the invention, the method by which subscriber unit 30 determines when to transmit the PSMM is described in US Patent No. 5,267,261 entitled "Mobile Station Assisted Soft Handoff in a CDMA Cellular Communications System" incorporated herein by reference ('261), and Chapter Six of the IS-95 standard.

10 Additionally, in the preferred embodiment of the invention, the PSMM indicates the pilot PN code phase (PILOT_PN_PHASE₂) of the pilot channel received from the second base station when detected by the subscriber unit 30. In the preferred embodiment, the pilot PN code phase is calculated as follows:

15

$$\text{PILOT_PN_PHASE}_2 = [\text{PILOT_ARRIVAL}_2 + (64 \times \text{PILOT_PN}_2)] \bmod 2^{15}. \quad (1)$$

PILOT_PN₂ is the PN offset index of the second base station 32b which, as noted above, is in units of 64 pilot PN chips. The mod 2¹⁵ term
20 accounts for the period of the pilot PN code in PN chips, and PILOT_ARRIVAL₂ is the arrival time at the subscriber unit 30 of the earliest usable multipath component of the pilot channel from the second base station 32b relative to the time reference in PN chips. In the preferred
25 embodiment of the invention, the time reference is established by the earliest arriving pilot channel from any base station 32, including any multipath component of that pilot channel. In general, the earliest arriving pilot channel is from the closest base station 32, which in the example shown is the first base station 32a. Thus, PILOT_PN_PHASE₂ is simply the
30 difference between the arrival time of the pilot channel from the first base station 32a and the arrival time of pilot channel from the second base station 32b in PN chips, plus the pilot channel offset of the second base station in PN code chips, which is 64*PILOT_PN₂.

Upon receipt of PSMM 57, the selector updates the pilot database with the value PILOT_PN_PHASE₂. The pilot database (PDB) keeps track of a set
35 pilot channels that have been detected by subscriber unit 30 including the associated pilot PN code phase PILOT_PN_PHASE of those pilot channels. The PDB also calculates the one way propagation delay (propagation delay) between subscriber unit 30 and each base station 32 in the active set as half the round trip delay. That is, the PDB calculates the propagation delay for

each base station 32 that the subscriber unit 30 is currently interfacing with. In the present case, the PDB would only calculate the propagation delay to the first base station 32a since it is the only base station with an interface has been established. As described in greater detail below, the selector then uses
5 PILOT_PN_PHASE₂ and the propagation delay to the first base station 32a to calculate the propagation delay to the second base station 32b to aid in the acquisition of the reverse link signal at the second base station 32b.

Still referring to FIG. 3, to maintain the accuracy of the round trip delay stored in the PDB, the first base station 32a measures the round trip
10 delay of transmissions exchanged with from subscriber unit 30 (RTD) at step 56. The round trip delay may be measured at the first base station 32a in various ways, including comparing the state of the PN codes used to demodulate the reverse link signal with the state of a zero offset PN code, or by comparing the time at which frame edges occur at transmission and
15 reception.

If it is determined at step 58 that the change in the round trip delay is less than the duration of 2 PN chips, step 56 is performed again. Since the spreading rate as specified by IS-95 is 1.2288 Megachips per second (Mcps), the threshold used in the preferred embodiment of the invention is 1.6276
20 microseconds (μs).

If it is determined at step 58 that the change in the round trip delay is equal to or greater than 2 PN chips, the first base station 32a notifies the selector of the new propagation delay at step 60 via timing update message 62. While the use of 2 PN chips as the threshold for notifying the selector is
25 preferred, other thresholds are consistent with the use of the present invention.

At step 64, BSC 36 receives timing update message 62 and updates the pilot database (PDB) at step 64. As noted above, the PDB keeps track of the round trip delay to each base station 32 with which communication has been
30 established. To perform the update, the round trip delay within the PDB is updated to that indicated in timing update message 62.

At step 66, BSC 36 receives PSMM 57 indicating that the pilot channel from the second base station 32b has been detected with a particular strength and duration and the pilot PN code phase PILOT_PN_PHASE₂ of the pilot
35 channel. BSC 36 responds by recording detection of the pilot channel from the second base station 32b in the PDB along with the pilot PN code phase PILOT_PN_PHASE₂.

At step 68, BSC 26 determines whether a soft handoff (SH) is necessary. In the preferred embodiment of the invention this

determination is performed in accordance with the above referenced '261 patent, and as described in the IS-95 standard. In general, however, the determination is based on whether the pilot channel from base station 32b has been detected with a second predetermined strength and duration. If it is determined at step 68 that a soft handoff is not necessary, BSC 26 performs step 64 again.

If it is determined at step 68 that a soft handoff is necessary, BSC 26 calculates the estimated arrival state at the second base station 32b of the reverse link signal PN code based on the round trip delay and the pilot PN code phase $PILOT_PN_PHASE_2$ as described below. Base station 32b then begins acquisition of the reverse signal at step 72 using the reverse link PN code initialized at the estimated arrival state. By initializing the PN codes at the estimated arrival state, the time required for the acquisition process is, on average, reduced, as the state of PN codes is more likely to be close to the actual state of the received reverse link signal reducing the necessary searching.

FIG. 4 is a timing diagram illustrating calculation of the estimated arrival state of the reverse link signal PN code within BSC 26 when performed in accordance with one embodiment of the invention. Time is represented on the horizontal axis, and the position of the first base station 32a (labeled BS1), the second base station 32b (labeled BS2), and subscriber unit 30 (labeled SU) is shown on the vertical axis. The graphed lines represent exemplary transmissions between these various systems.

The estimated arrival state is calculated by first determining the difference in the propagation delays between the second base station 32b and subscriber unit 30, and the first base station 32a and subscriber unit 30 as $pd_{b2} - pd_{b1}$ (Δpd), where pd_{b2} is the propagation delay to the second base station 32b and pd_{b1} is the propagation delay to the first base station 32a. As noted above the PDB calculates the propagation delay as one-half the round trip delay.

In one embodiment of the invention, Δpd is calculated by the selector as the pilot code phase $PILOT_PN_PHASE_2$ minus the $PILOT_PN$ offset of the reference pilot channel (from the first base station 32a in the example) in PN chips as follows:

$$\Delta pd = [PILOT_PN_PHASE_2 - (64 \times PILOT_PN_2)] \bmod 2^{15} \quad (2)$$

Equation (2) simply removes the PN offset for second base station 32b in PN chips (i.e. $64 \times PILOT_PN_2$) from the pilot phase of the second base

station 32b (PILOT_PN_PHASE₂) yielding the difference between the arrival time of the reference pilot channel from the first base station 32a and the pilot channel from the second base station 32b in PN chips. The difference in the arrival time of the two pilot channel corresponds to the difference in the propagation delay from subscriber unit 30 to the first base station 32a and the propagation delay from subscriber unit 30 to the second base station 32b, i.e. Δpd . Those skilled in the art will recognize other ways to calculate Δpd using the information stored in the PDB.

Using the difference in the propagation delays Δpd , the actual propagation delay from the second base station 32b to subscriber unit 30 pd_{b2} can be determined as $pd_{b1} + \Delta pd$, or $pd_{b1} + (pd_{b2} - pd_{b1})$. As shown in FIG. 4, the propagation delay pd_{b2} is the sum of the propagation delay from the first base station 32a to the subscriber unit 30 pd_{b1} and difference in the propagation delays Δpd .

Once pd_{b2} is calculated, the total propagation delay (pd_{tot}) from the first base station 32a to subscriber unit 30, and then from subscriber unit 30 to the second base station 32b is calculated as $pd_{b2} + pd_{b1}$. The arrival state of the reverse link PN code at the second base station 32b is then estimated based on system time at the first base station 32b plus the total propagation delay (pd_{tot}). This calculation provides a reasonable estimate of the arrival state of the reverse link PN code at the second base station 32b because the internal timing of subscriber unit 30 is set one propagation delay pd_{b1} later than system time at the first base station 32a, and the reverse link signal generated by subscriber unit 30 is received at the second base station 32b one propagation delay pd_{b2} after that. Hence, the total propagation delay pd_{tot} is equal to $pd_{b2} + pd_{b1}$.

Referring again to FIG. 3, the total propagation delay pd_{tot} is transmitted to the second base station 32b in signaling message 71 (FIG. 3). The second base station 32b then estimates the arrival state of the reverse link signal as the pilot PN code state minus propagation delay pd_{tot} as follows:

$$ARRIVAL_STATE = [PILOT_PN_STATE_{zero_offset} + pd_{tot}]. \quad (3)$$

PILOT_PN_STATE_{zero_offset} is the PN code state of the zero offset pilot sequence and pd_{tot} is the sum of the propagation delay from the first base station 32a to the subscriber unit 30 and the propagation delay from the second base station 32b to the subscriber unit 30. In the preferred embodiment of the invention, the zero offset pilot PN code state is

determined based on the system time known to each base station 32. In alternative embodiments of the invention, the estimated arrival state of the pilot PN code for the reverse link signal could be calculated by the selector rather than by the second base station 32b.

5 It will be apparent that the arrival state of the reverse link signal will most likely correspond to the zero offset PN code state 32a plus propagation delay pd_{tot} because the internal timing of subscriber unit 30 is set one propagation delay pd_{b1} later than system time at the first base station 32a, and the reverse link signal generated by subscriber unit 30 using that internal
10 timing is received at the second base station 32b one propagation delay pd_{b2} after that. Thus, by tracking the propagation delay to the first base station 32a pd_{b1} and the pilot PN code phase $PILOT_PN_PHASE_2$ of the second base station 32b, the propagation delay to the second base station 32b pd_{b2} and the total propagation delay pd_{tot} can be calculated, and the arrival state of the
15 reverse link PN codes at the second base station estimated.

As noted above, the PN codes used for the reverse link signal are generated with an offset of zero, rather than offset by some non-zero PN offset value as performed for the forward link. However, any such non-zero PN offset in the reverse link PN code can be accounted for in equation (3) by
20 substituting the offset pilot PN sequence for the zero offset pilot PN sequence.

At step 73 the selector begins to perform the selection and distribution function by forwarding traffic data to the second base station 32b as well as the first base station 32a, and selecting from data received from the second
25 base station 32b.

At step 74, the selector within BSC 26 initiates the soft handoff by transmitting handoff/extended-handoff direction message (HDM) 76 to subscriber unit 30 via the forward link traffic channel from the first base station 32a. At step 78, the subscriber unit receives HDM 76 and begins to
30 process the traffic channel from the second base station 32b, and the soft handoff has been established. Each system continues to process the call in soft handoff at steps 80a - d.

By tracking the round trip delay to the first base station 32a (RTD), and updating that round trip delay only when a change that is greater than a
35 predetermined amount occurs, the described invention allows the round trip delay to be tracked accurately at a base station controller 36 while minimizing the number of signaling message exchanged between the base station 32 and the base station controller 36. Maintaining an accurate measurement of the round trip delay using a minimum number of

signaling messages, in turn, allows an estimated arrival state of the reverse link signal at the second base station 32b to be accurately calculated, without reducing the communication capacity between the base station 32 and the subscriber unit 30 to be used for transmitting user data. This increases the number of calls that be conducted, or decreases the necessary signaling capacity between the base station and the base station controller.

Thus, a novel and improved method and apparatus for efficiently performing a soft handoff is described. The previous description of the preferred embodiment is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. In particular, while the invention is described in the context of a particular configuration of a base station controller, the present invention may be also be implemented using alternatively configured base station controllers. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

20

WE CLAIM:

CLAIMS

1. A method for tracking a first propagation delay between a first
2 base station and a subscriber unit comprising:
tracking changes in the first delay to said first base station; and
4 notifying a base station controller when said first delay changes by a
predetermined amount.

2. The method as set forth in claim 1 wherein said predetermined
2 amount is equal to approximately 1.6276 μ s.

3. The method as set forth in claim 1 or 2 wherein said base
2 station controller is coupled to a second base station.

4. The method as set forth in claim 3 further comprising:
calculating a second delay as a pilot channel phase offset of said
second base station less a pilot offset of said second base station; and
initiating an acquisition sequence at said second base station using
said first propagation delay and said second delay.

5. The method as set forth in any preceding claim wherein the
tracking comprises comparing the state of a modulation PN code and a
demodulation PN code.

6. A system for providing wireless communications, the system
2 comprising:
subscriber unit for generating pilot strength measurement report
4 indicating a phase offset of received pilot channel;
first base station for generating a timing update message when a first
6 propagation delay between said first base station and said subscriber unit
changes more than a predetermined amount;
8 base station controller for generating an estimated delay using said
phase offset and said first delay; and
10 second base station for performing a signal acquisition initiated at said
estimated delay.

7. The system as set forth in claim 6 wherein said predetermined
2 amount is approximately 1.6276 ms.

8. A wireless telecommunications system for tracking a first delay
2 to a subscriber unit comprising:
a base station for generating a timing update message when said first
4 delay changes by a predetermined amount; and
a base station controller for updating a pilot database using said
6 timing update message.

9. The wireless communication system of claim 8 wherein said
2 base station controller is further for generating an estimated delay between a
second base station and the subscriber unit.

10. The wireless communication system of claim 9 wherein said
2 second base station performs a signal acquisition initiated at said estimated
delay.

11. The wireless communication system of claim 9 or 10 wherein
2 said estimated delay is a timing difference received from the subscriber unit
minus said first delay.

12. A wireless telecommunications system for tracking a first delay
2 to a subscriber unit comprising:
transmission means for generating a timing update message when
4 said first delay changes by a predetermined amount; and
controller means for updating a pilot database using said timing
6 update message.

13. The wireless communication system of claim 12 wherein said
2 controller means is further for generating an estimated delay between a
second transmission means and the subscriber unit.

14. The wireless communication system of claim 13 wherein said
2 second transmission means performs a signal acquisition initiated at said
estimated delay.

15. The wireless communication system of claim 13 or 14 wherein
2 said estimated delay is a timing difference received from the subscriber unit
minus said first delay.

16. A controller for controlling communication with a subscriber unit by measuring the time taken for a signal to travel from one communication system and back via the subscriber unit and selecting either the one or another communication system for communication with the subscriber unit depending on the time taken.

1/4

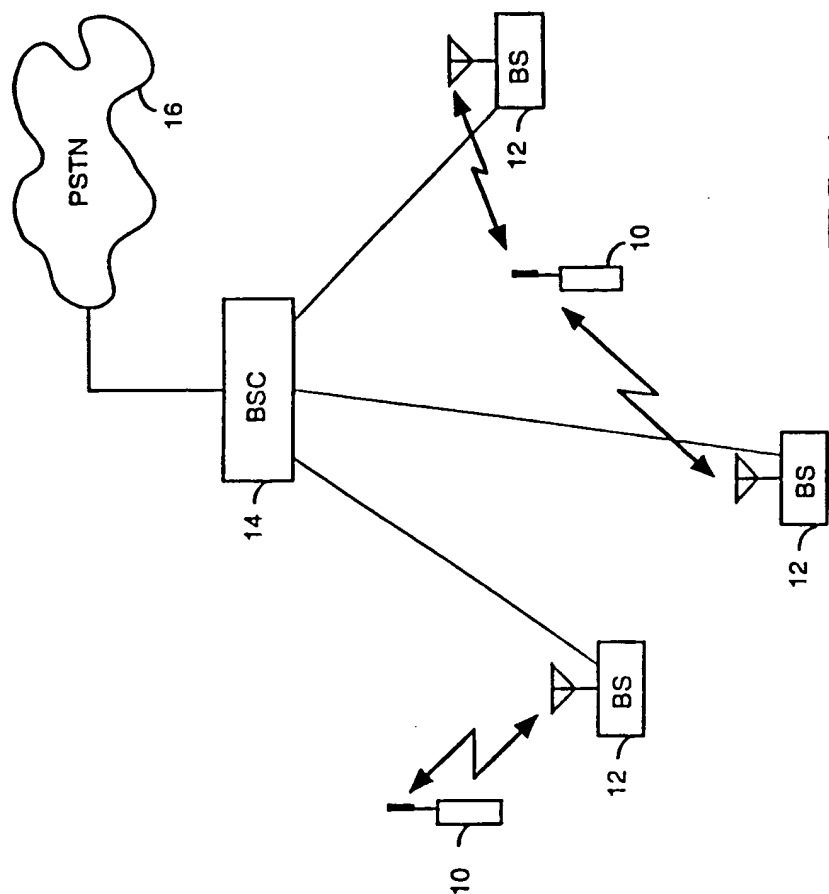


FIG. 1

2/4

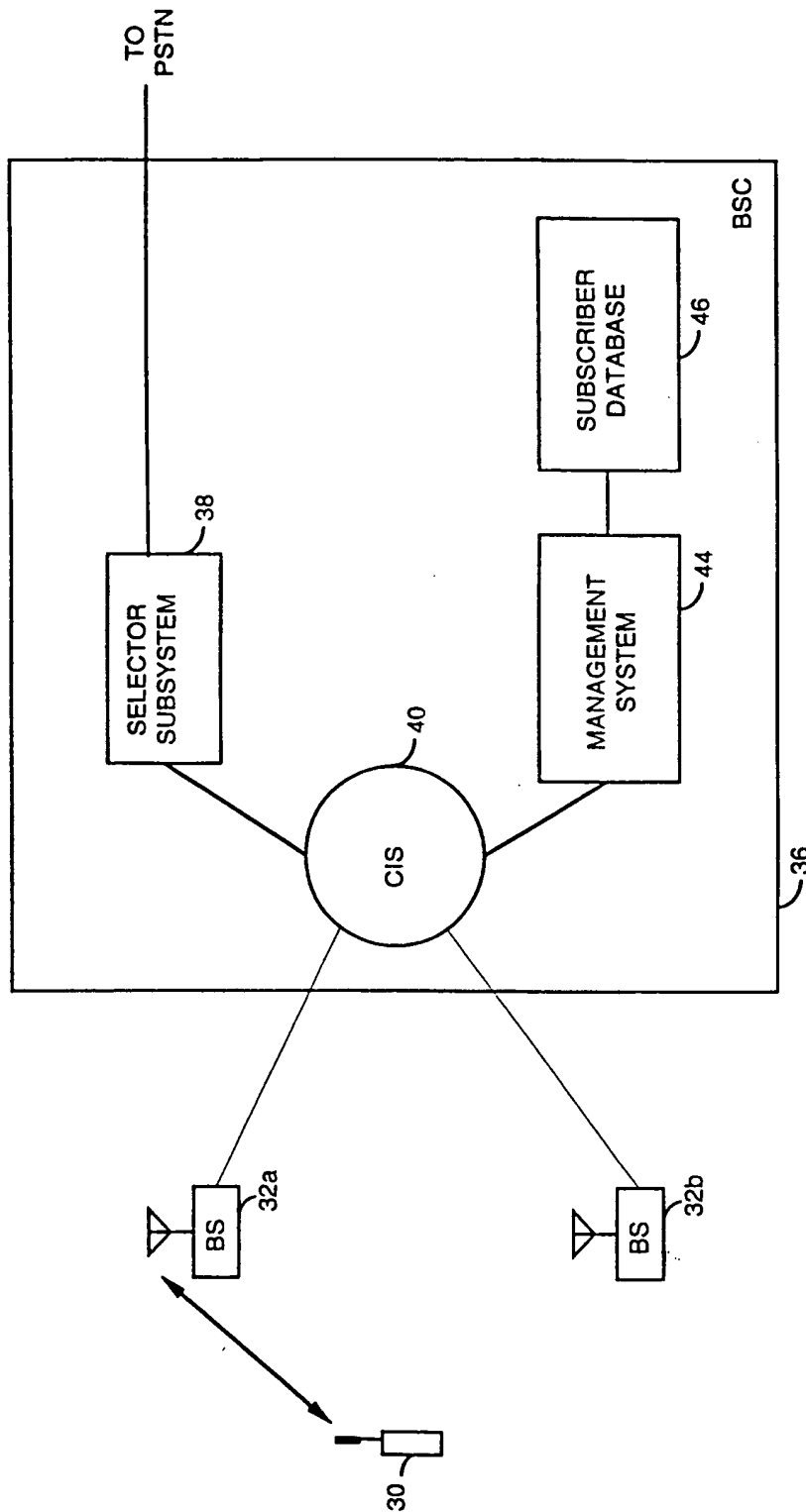


FIG. 2

3/4

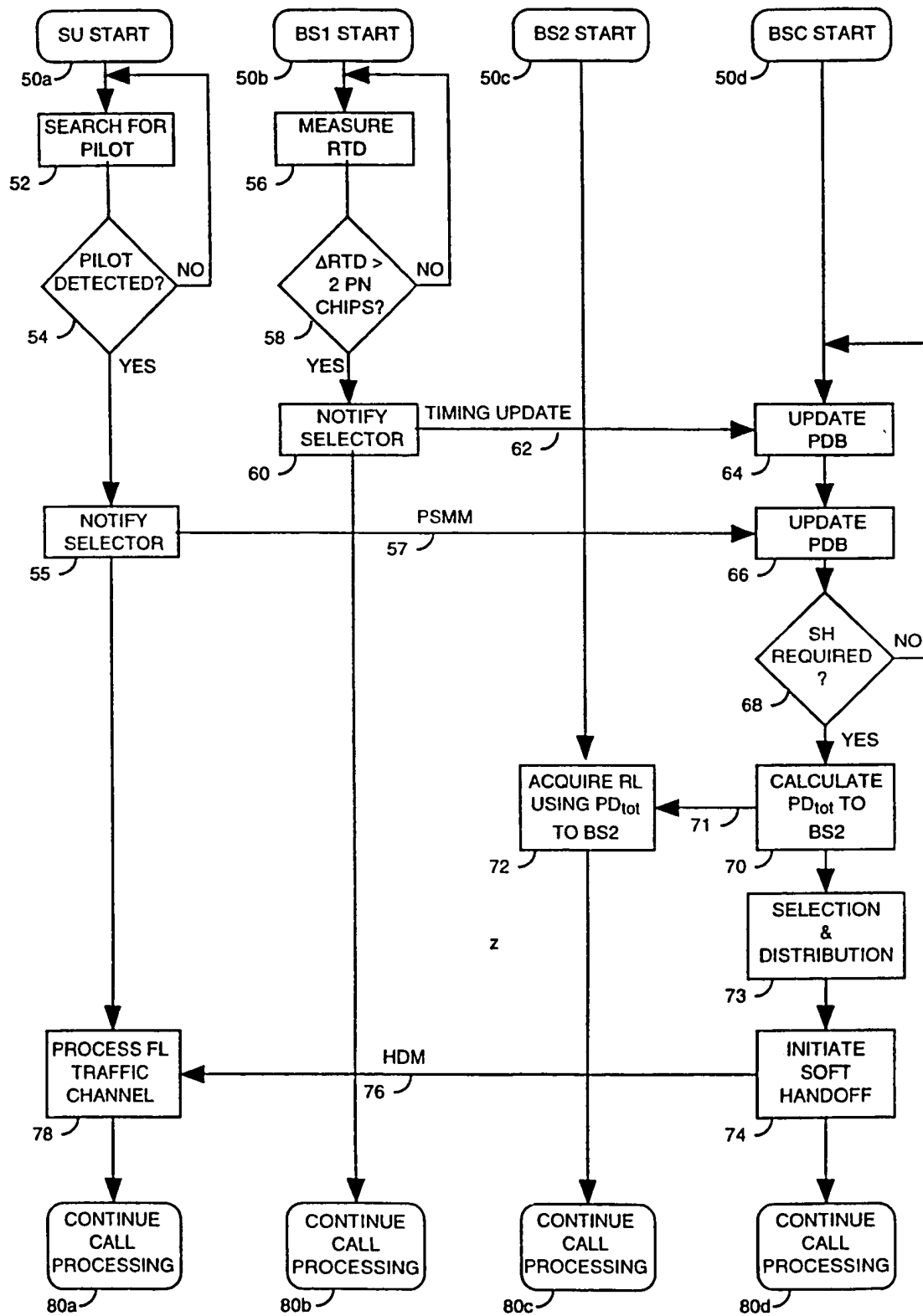


FIG. 3

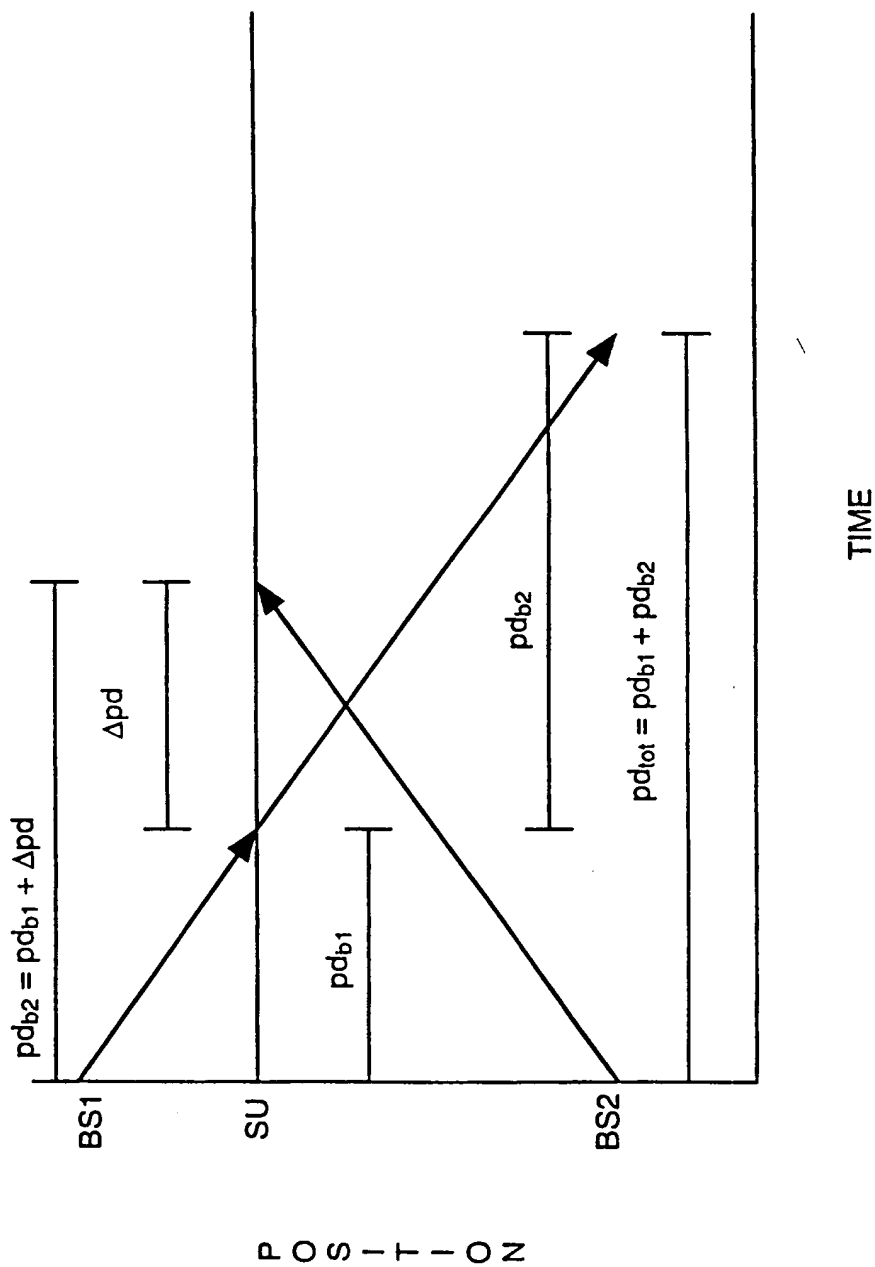


FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 08369

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H0407/38

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H040

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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P,X	WO 97 44970 A (QUALCOMM INC.) 27 November 1997 see claims 1,2 ---	1-16
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P,X	WO 97 43837 A (MOTOROLA INC.) 20 November 1997 see page 8, line 30 - page 10, line 17 ---	1,3,4,6, 8-16
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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"Z" document member of the same patent family

Date of the actual completion of the international search

2 October 1998

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INTERNATIONAL SEARCH REPORT

Int. l. Application No

PCT/US 8369

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	see page 3, line 24 - line 31 see page 5, line 4 - line 14 ---	4,6, 9-11, 13-15
Y	WO 94 21057 A (TELEFONAKTIEBOLAGET LM ERICSSON) 15 September 1994 see claims 1-5 ---	4,6, 9-11, 13-15
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